ACETYLENE-BASED ADDITION FOR HOMOGENEOUS-CHARGE COMPRESSION IGNITION (HCCI) ENGINE OPERATION

FIELD OF THE INVENTION

[0001] The present invention relates to internal combustion engines, and more particularly to homogeneous-charge compression ignition (HCCI) engines.

BACKGROUND OF THE INVENTION

[0002] Homogeneous-charge compression ignition (HCCI) engines compress a homogeneous or nearly homogeneous mixture of air, engine exhaust and fuel vapor (intake charge) until the mixture auto-ignites. Auto-ignition induces combustion of the air and fuel vapor mixture, which drives engine pistons to produce work. The auto-ignition reaction is a relatively low temperature, quick reaction that results in low nitrogen oxide (NO_X) emissions and improved engine efficiency. One difficulty of operating an HCCI engine has been to properly control the combustion process so that robust and stable combustion with low emissions, optimal heat release rate and low noise can be achieved over a wide range of operating conditions.

[0003] At medium engine speed and load, a combination of valve timing strategy and exhaust re-breathing during the intake stroke has been effective in providing adequate heating of the intake charge so that auto-ignition during the compression stroke leads to stable combustion with low noise. This method, however, may not be satisfactory at or near idle conditions. As the idle speed and load is approached from a medium speed

and load condition, the exhaust temperature decreases. At near idle, there can be insufficient energy in the re-breathed exhaust to produce reliable auto-ignition. As a result, the cycle-to-cycle variability of the combustion process is too high to enable stable combustion at the idle condition.

SUMMARY OF THE INVENTION

[0004] Accordingly, the present invention provides a vehicle driven by a homogeneous-charge compression ignition (HCCI) engine. The vehicle includes a fuel supply that supplies a hydrocarbon fuel in a first amount and an acetylene supply that supplies an acetylene-based component in a second amount. A cylinder has a piston reciprocally driven therein. The cylinder receives a combustion mixture including a third amount of air, the first amount of hydrocarbon fuel and the second amount of the acetylene-based component. The piston compresses the combustion mixture to induce auto-ignition of the combustion mixture.

[0005] In one feature, the acetylene-based component consists essentially of acetylene.

[0006] In another feature, the acetylene-based component includes acetylene and hydrogen.

[0007] In another feature, the vehicle further includes an inlet valve in the engine that is movable between an open position and a closed position. When in the open position the inlet valve enables a flow of the combustion mixture into the cylinder.

[0008] In another feature, the vehicle further includes a fuel injector that selectively injects the first amount of the hydrocarbon fuel into the

cylinder, an acetylene injector that injects the second amount the acetylene-based component into either the cylinder or the intake manifold and an inlet valve movable between an open position and a closed position. When in the open position the inlet valve enables a flow of the third amount of the air into the cylinder to mix with the hydrocarbon fuel and the acetylene-based component to produce the combustion mixture.

[0009] In another feature, the acetylene supply is a plasma or thermal generator that converts a portion of the hydrocarbon fuel to produce the second amount of the acetylene-based component.

[0010] In still another feature, the second amount of the acetylene-based component is within a range of up to 20 weight % of the fuel mixture.

[0011] In another feature, the second amount of the acetylene-based component varies based on a load of the HCCI engine.

[0012] In yet another feature, the second amount of the acetylene-based component remains constant regardless of a load of the HCCI engine.

[0013] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0015] Figure 1 is a functional block diagram of a vehicle having a homogeneous-charge compression ignition (HCCI) engine according to the present invention; and

[0016] Figure 2 is a schematic illustration of a cylinder of the HCCI engine.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0018] Referring now to Figure 1, a functional block diagram of a vehicle 10 is shown. The vehicle 10 includes a homogeneous-charge compression ignition (HCCI) engine 12. The HCCI engine 12 includes a throttle 14 and an intake manifold 16. Air is drawn into the HCCI engine 12 through the throttle 14 and the intake manifold 16 and into a cylinder 18. Although only a single cylinder 18 is shown, it is appreciated that the HCCI engine 12 can include multiple cylinders 18. The air is part of a combustion mixture that is combusted within the cylinder 18 to produce work.

[0019] A hydrocarbon fuel is supplied to the HCCI engine 12 from a fuel system 20. A fuel injector 22 is associated with the cylinder 18. The fuel injector 22 regulates the amount of fuel that is included in the combustion mixture. An acetylene-based component is supplied to the HCCI engine 12 from an acetylene source 24. The acetylene-based component can include either pure acetylene (C_2H_2) or an acetylene-hydrogen mixture (C_2H_2 - H_2), or a mixture of acetylene, hydrogen, and other products which accompany

acetylene production. An acetylene injector 26 regulates the amount of the acetylene-based component that is included in the combustion mixture.

[0020] The acetylene source 24 can be a plasma generator that converts a portion of the hydrocarbon fuel, supplied by the fuel system, to acetylene or the acetylene-hydrogen mixture. Using an appropriately chosen voltage and frequency, the plasma generator dissociates molecules of the hydrocarbon fuel into a variety of atomic, ionic and molecular fragments including hydrogen atoms (H), carbon atoms (C) and small carbon-containing molecules such as CH and CH_2. As the fragments cool they recombine to predominantly form acetylene, hydrogen and other molecules. For lower energy plasma generators, the hydrocarbon fuel is dissociated into a variety of molecular fragments that undergo chemical reactions to produce acetylene, hydrogen and other molecules. It is also anticipated that the acetylene source 24 can be a separate acetylene tank or can be produced on-board by other means. Such other means include, but are not limited to a high-temperature reactor containing carbon or hydrogen or a thermal reactor that converts the hydrocarbon fuel to acetylene and hydrogen.

[0021] The ratio between acetylene and hydrogen in the acetylene-hydrogen mixture is based on the carbon to hydrogen ratio of the fuel used to make the mixture. Assuming no other products are formed, the following reaction stoichiometry governs:

$$C_mH_n \rightarrow (m/2)C_2H_2 + ((n-m)/2)H_2$$

for $n > m$, which holds true for most relevant fuels. For example, for gasoline $m = 7$ and $n = 14$ approximately.

[0022] A controller 28 controls operation of the HCCI engine 12. The controller 28 communicates with the fuel injector 22 and the acetylene injector 26 to control respective amounts of the hydrocarbon fuel and acetylene-based component that is included in the combustion mixture. The controller 28 also communicates with the fuel system 20 and acetylene source 24 to control operation of each. A speed sensor 30 generates an engine speed signal that is sent to the controller 28. Engine load is determined based on driver pedal input and fueling rates are determined in response to engine speed and load. Other sensors, such as a manifold absolute pressure (MAP) sensor 32, may be located in the intake manifold 16. These other sensors send signals to the controller 28.

[0023] Referring now to Figure 2, operation of the HCCI engine 12 will be discussed. The cylinder 18 includes a piston 34 slidably disposed and reciprocally driven therein. One or more inlet valves 36 selectively block intake ports 38 that are in fluid communication with an intake path 40 of the intake manifold 16. One or more exhaust valves 42 selectively block exhaust ports 44 that are in fluid communication with an exhaust path 46 of an exhaust manifold (not shown). During operation, a combustion mixture is either drawn into the cylinder 18 or components thereof are mixed in the cylinder 18. With both the inlet valves 36 and exhaust valves 42 closed (i.e., blocking the intake ports 38 and exhaust ports 44) the combustion mixture is compressed within the cylinder 18 by the piston 34. The temperature and pressure of the combustion mixture increase to the point of auto-ignition and a combustion reaction occurs. Exhaust gas is created by the combustion reaction. The exhaust valve 42 opens to exhaust the exhaust gas from the cylinder 18.

[0024] The combustion mixture can be created in several manners. In one manner, the fuel injector 22 and acetylene injector 24 are disposed upstream of the intake port 38. The acetylene-based component, fuel and air are mixed to form the combustion mixture prior to intake into the cylinder 18 through the intake port 38. In an alternative manner, the fuel injector 22 and acetylene injector 24 can respectively inject the fuel and the acetylene-based component directly into the cylinder 18. Air is drawn into the cylinder 18 through the intake port 38 and mixes with the injected fuel and acetylene-based component to form the combustion mixture. As another alternative, either the fuel injector 22 or the acetylene injector 24 can be disposed upstream of the intake port 38 to inject either the fuel or the acetylene-based component into the air stream flowing through the intake path 40. The other of the fuel injector 22 or the acetylene injector 24 directly injects either the fuel or the acetylene-based component to mix with the mixture drawn into the cylinder 18 through the intake port 38.

[0025] The acetylene or the acetylene-hydrogen mixture components of the combustion mixture make auto-ignition easier. More specifically, it is believed that the initiation reaction of oxygen (O_2) with acetylene occurs at a lower temperature than the O_2 reaction with other fuel components. As a result, the initiation reaction starts a chain reaction involving the other fuel components to induce complete combustion of the combustion mixture. The chain reaction begins earlier in the engine cycle, which allows auto-ignition to occur earlier. Thus, the fueling rate to the engine can be reduced (e.g., in the case of low engine load) and still achieve the same auto-ignition time as a higher fueling rate without acetylene or an

acetylene-hydrogen mixture. It is also believed that the hydrogen (H_2) in the acetylene-hydrogen mixture enables an extra boost to auto-ignition through the reaction: $OH + H_2 \rightarrow H_2O + H$ and subsequent reactions.

[0026] It is also anticipated that the combustion mixture can further include an amount of recirculated exhaust gas. To achieve this, a portion of exhaust gas exiting the engine 12 is bled back into the cylinder 18 to mix with the other components of the combustion mixture. The recirculated exhaust gas improves auto-ignition of the combustion mixture.

[0027] The fueling rate to the HCCI engine 12 varies based on the engine load and speed. For low engine speeds and loads, the fueling rate is reduced and for high engine speeds and loads the fueling rate is increased. As mentioned above, the engine load is determined by driver pedal position and the controller 28 adjusts the fueling rate based on the engine load and speed.

[0028] The acetylene-based component induces auto-ignition at lower engine loads when the fueling rate is reduced. Preferably, the amount of acetylene-based component is within a range of 2 – 20 weight % of the fuel mixture. It is appreciated that any amount of acetylene present is desirable. Thus, even a small amount, greater than zero weight % or greater than 2 weight % is beneficial.

[0029] In one embodiment, the injection rate of the acetylene-based component is held constant as the fueling rate varies. As a result, the weight % of the acetylene-based component varies as the fueling rate varies. For example, as the fueling rate increases for higher engine loads, the weight % of the acetylene-based component decreases. As the fueling rate decreases

for lower engine loads, the weight % of the acetylene-based component increases. In an alternative embodiment, the acetylene-based component amount can vary. For example, the acetylene-based component can be injected during periods of low engine load to enable quicker auto-ignition and then can be reduced or ceased altogether during periods of high engine load.

[0030] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.